Elasticity of Diopside at High Pressure and High Temperature

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Introduction: Clinopyroxene is an important mineral in the compositional models of the Earth's mantle. However, its elastic properties at high pressure and high temperatures have remained less studied comparing to other upper mantle phases, such as olivine. Clinopyxene slowly dissolve into garnet with increasing in depth in the upper mantle, contributing to the observed seismic velocity discontinuity at 410 km depth. The elastic properties at high pressure and high temperature of this phase will help us to refine the mineral physics studies of the seismic features in the upper mantle and the transition zone.

Methods and Materials: We measured elastic wave velocities on a polycrystalline sample of diopside using ultrasonic Interferometry in conjunction with X-ray diffraction. The sample was hot-pressed using USCA-1000 high pressure apparatus at Stony Brook high pressure laboratory. It has ~ 1 mm in thickness and about 2.0 mm in diameter after final polishing for acoustic experiment. The acoustic experiment was performed in a DIA-type cubic anvil apparatus (SAM85) installed at the superwiggler beamline X17B1 at NSLS in Brookhaven National Laboratory. A dual mode Lithium Niobate transducer (10 degree Y-cut, 30 MHz for S wave and 50 MHz for P wave) mounted at the back of the WC anvil enabled us to collect travel time data for both P and S waves in a single experiment. Cubic boron epoxy cube (6.15 mm edge length) was used as pressure medium. The sample was placed in the center of the boron epoxy cube with NaCl and BN as surrounding materials. An alumina buffer rod was inserted into the cell assembly between the WC anvil and the sample with gold foils (2 micron thickness) placed at the interface between sample and buffer rod as well as at the buffer rod and WC anvil interface to enhance the mechanical coupling. The sample pressure was determined using Decker pressure scale from the X-ray diffraction data for NaCl.

Results: P and S wave travel times were measured to 9 GPa and 1273 Kelvin. In the course of high pressure and high temperature experiment, the pressure was first increased to its designated pressure before heating. After reaching designated peak P-T condition, travel time data were collected during cooling to room temperature while the oil pressure was held constant. The reason for doing this is that the solid pressure medium exerts deviatoric stress on the sample in the cold pressing process as well as low temperatures. However, at temperatures above 400 degree centigrade, the NaCl surrounding the sample stated flowing, providing a hydrostatic stress environment to the sample. Three experiments were conducted at various peak P-T conditions as well as their consequent cooling cycles. The sample length at high pressure and high temperatures were obtained from sample volumes ($l/l_0=(V/V_0)^{(1/3)}$). P and S wave velocities can be calculated from the measured travel times and sample lengths and therefore the elastic bulk and shear moduli as well as their pressure and temperature derivatives can be obtained. The sample volumes at high pressure and high temperatures can be analyzed high temperature Birch-Murnaghan Eos, yielding information of the bulk modulus and its pressure and temperature derivatives.

Conclusions: We have measured the elastic P and S wave velocities of diopside to 9 GPa and 1273 Kelvin using polycrystalline sample in a DIA-type high pressure apparatus at X17B1, NSLS at Brookhaven National Lab. These results are important for the constructing velocity-depth models to constrain the composition of the upper mantle and the transition zone when compared with seismic data.